

FIG 1

Inventor: Ando, et al
 Docket No.: 12052.33USD1
 Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
 COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
 OF COLD-FORGING
 Attorney Name: Curtis B. Hamre
 Phone No.: (612) 336-4722
 Sheet 1 of 42

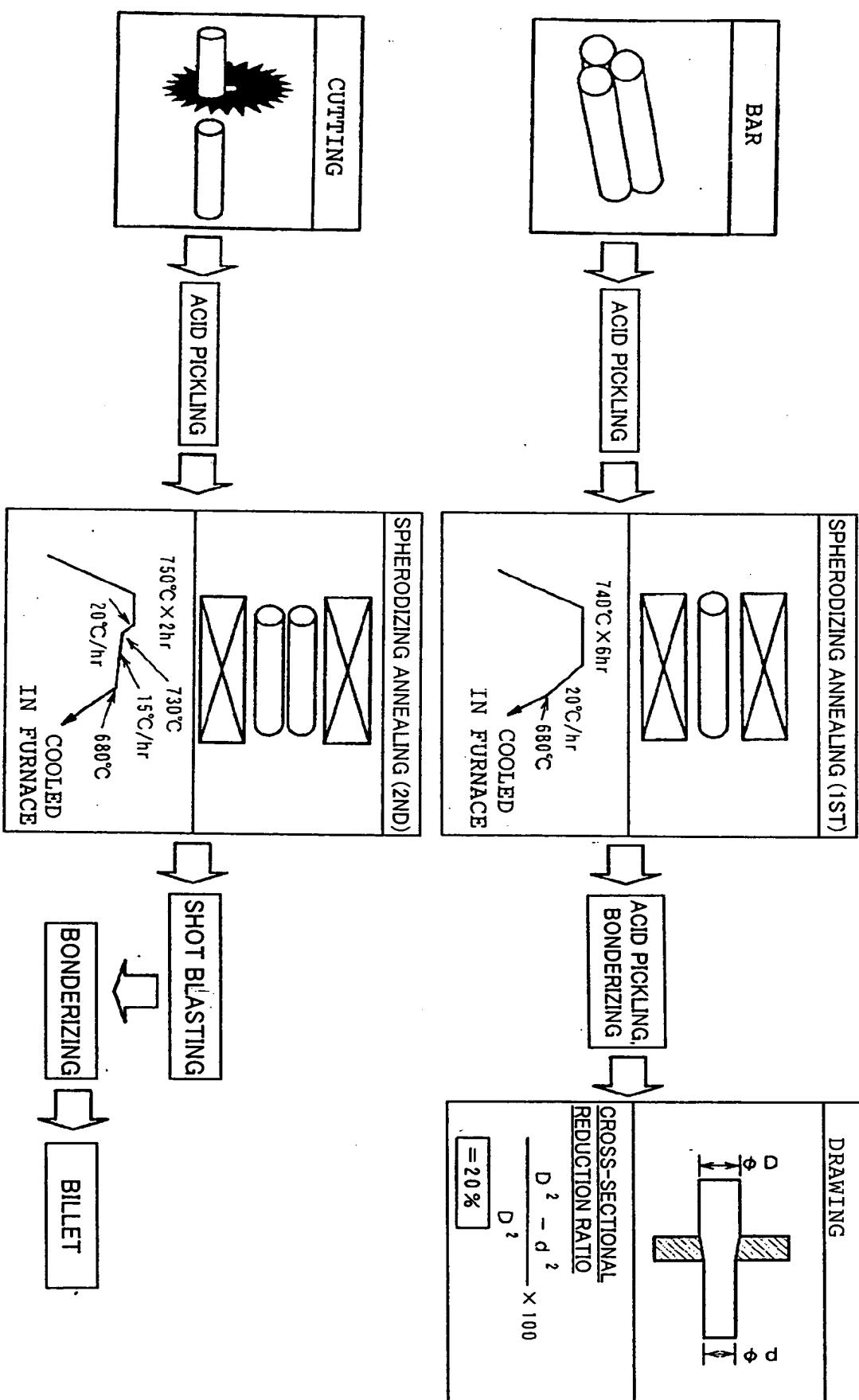
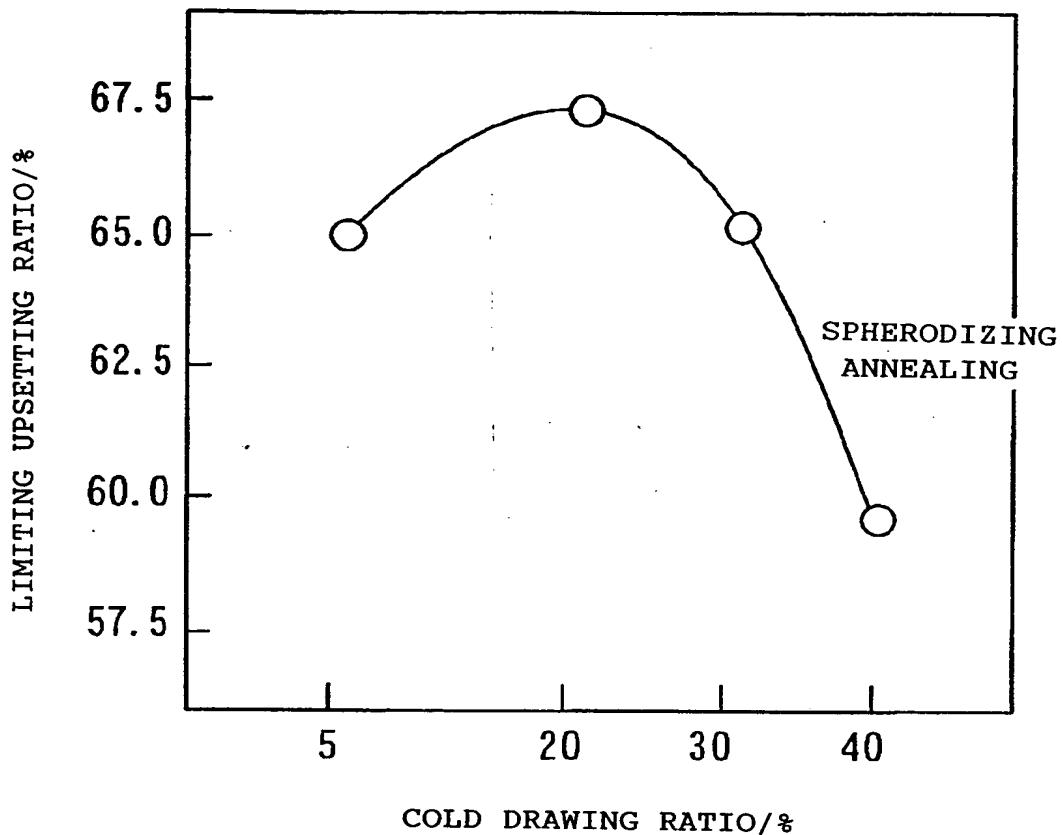
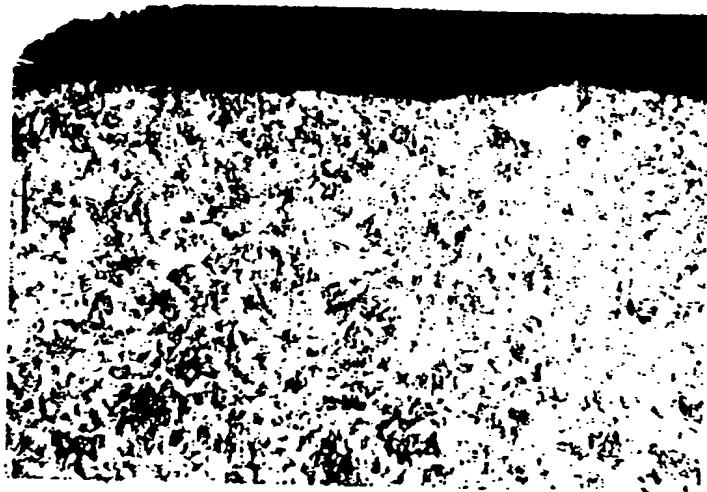


FIG. 2

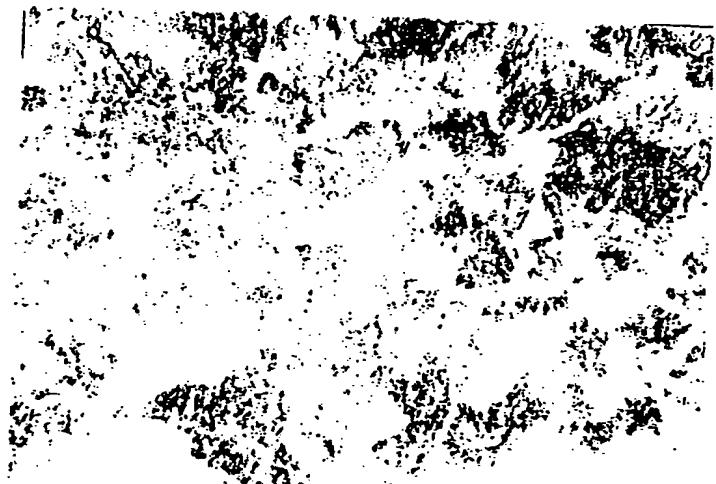


Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
OF COLD-FORGING
Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722
Sheet 3 of 42

FIG. 3



(a)



(b)

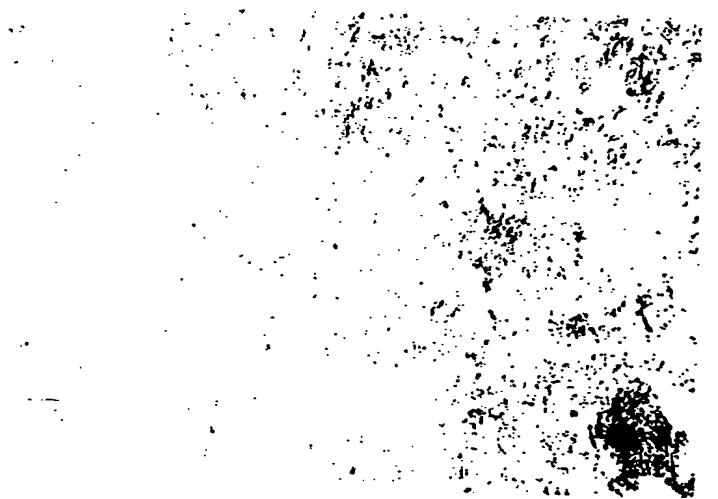
BEST AVAILABLE COPY

Inventor: Ando, et al
Docket No.: 12052.33USDI
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
OF COLD-FORGING
Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722
Sheet 4 of 42

FIG. 4



(a)

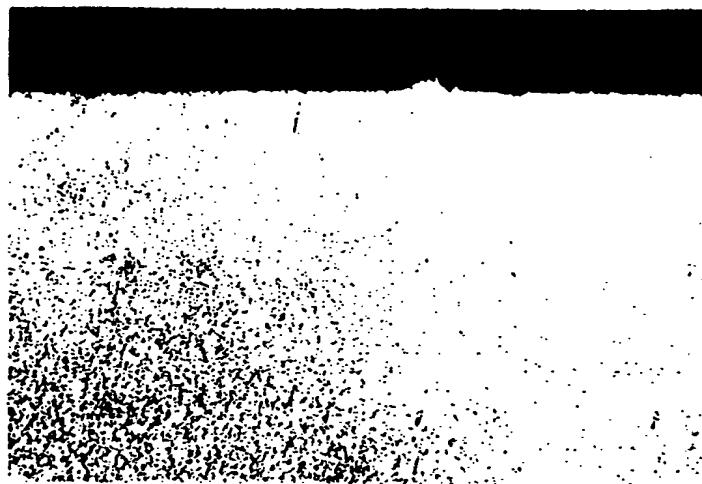


(b)

BEST AVAILABLE COPY

Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
OF COLD-FORGING
Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722
Sheet 5 of 42

FIG. 5



(a)



(b)

BEST AVAILABLE COPY

FIG. 6

BEST AVAILABLE COPY

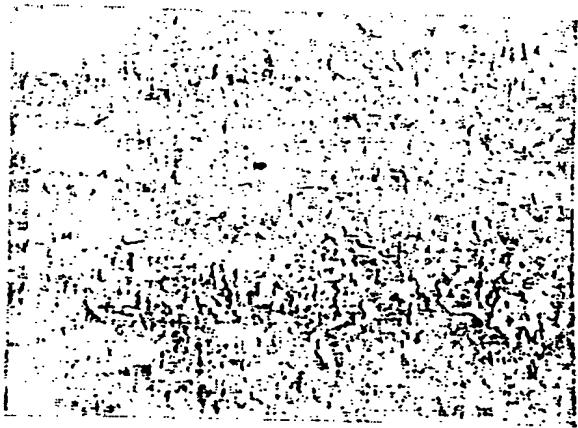
(A) MATERIAL 1

ASPECT RATIO = 506 %



(B) MATERIAL 2

ASPECT RATIO = 347 %



(C) MATERIAL 3

ASPECT RATIO = 300 %



FIG. 7

Inventor: Ando, et al

Docket No.: 12052.33USD1

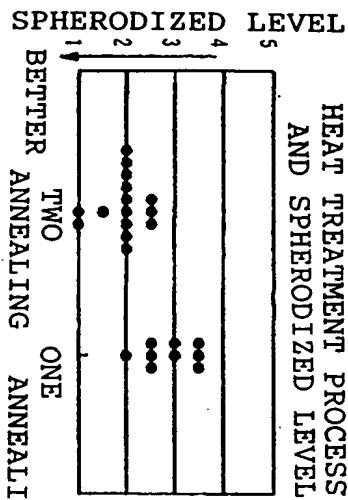
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD OF COLD-FORGING

Attorney Name: Curtis B. Hamre

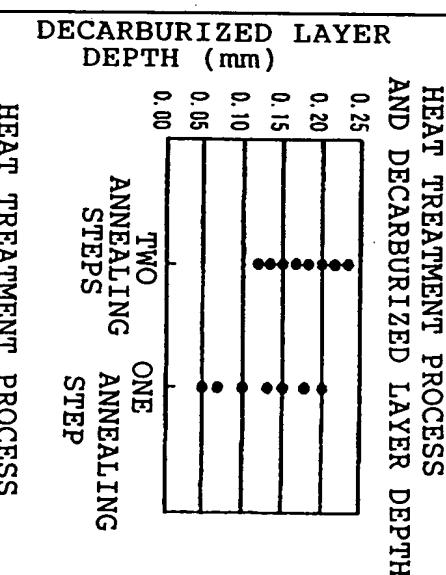
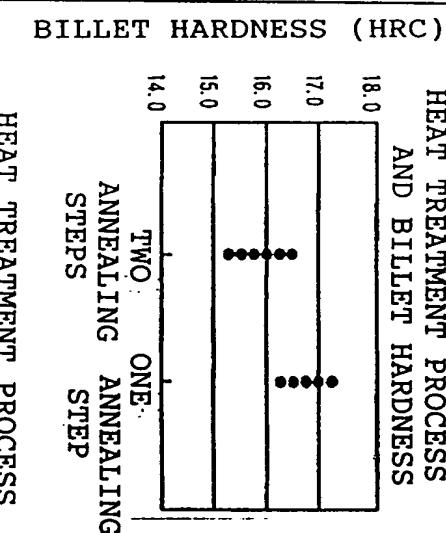
Phone No.: (612) 336-4722

Sheet 7 of 42

INTERNAL STRUCTURE



HEAT TREATMENT PROCESS



SURFACE LAYER STRUCTURE

ADVANTAGES OF
TWO ANNEALING
STEPS

INCREASE IN SPHERODIZED LEVEL

REDUCTION IN HARDNESS

CONVERSION OF SURFACE
LAYER INTO FERRITEINCREASE IN SURFACE
LAYER ELONGATION RATIO

FIG. 8

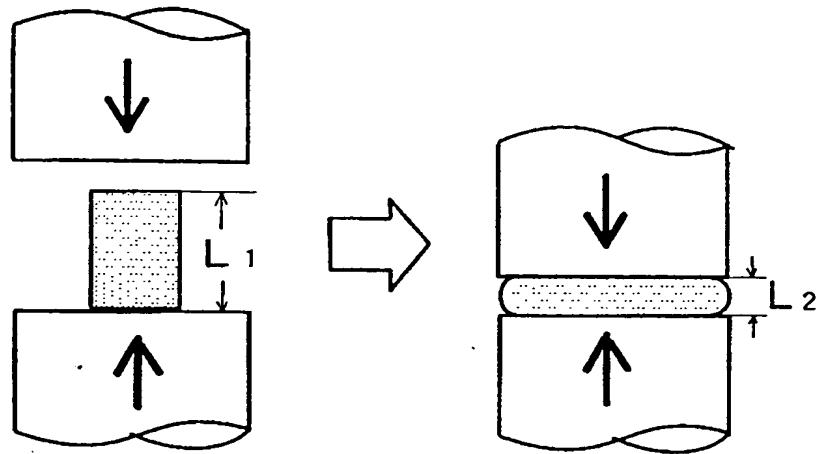


FIG. 9

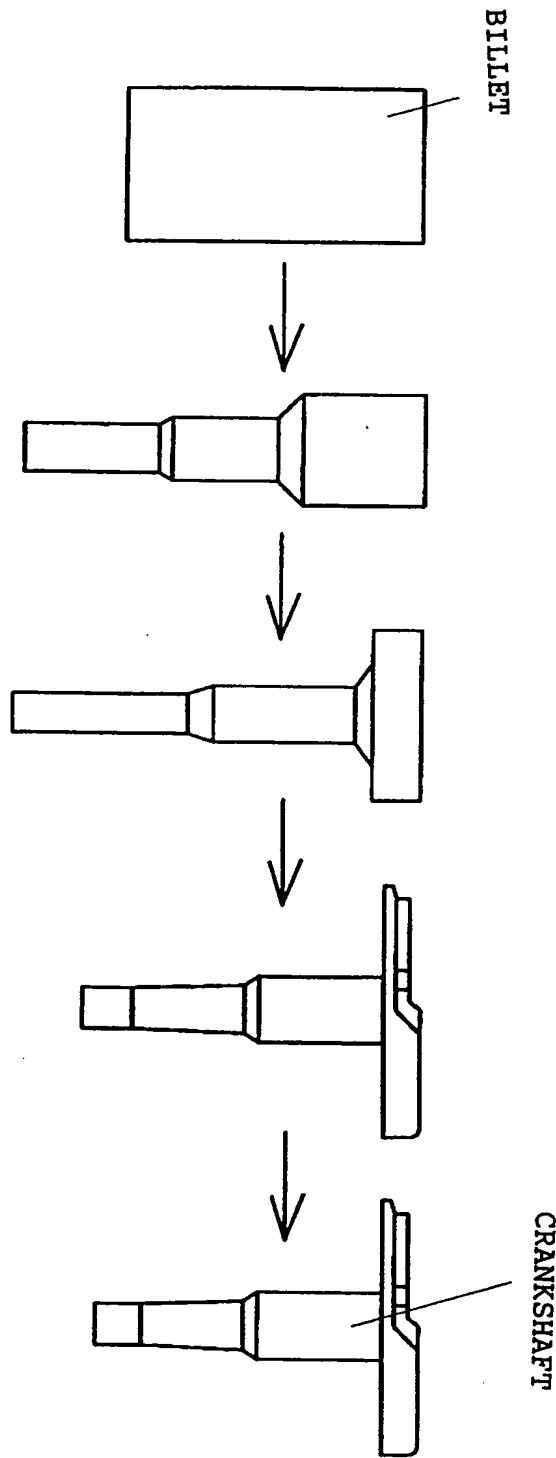


FIG. 10

Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
OF COLD-FORGING
Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722
Sheet 10 of 42

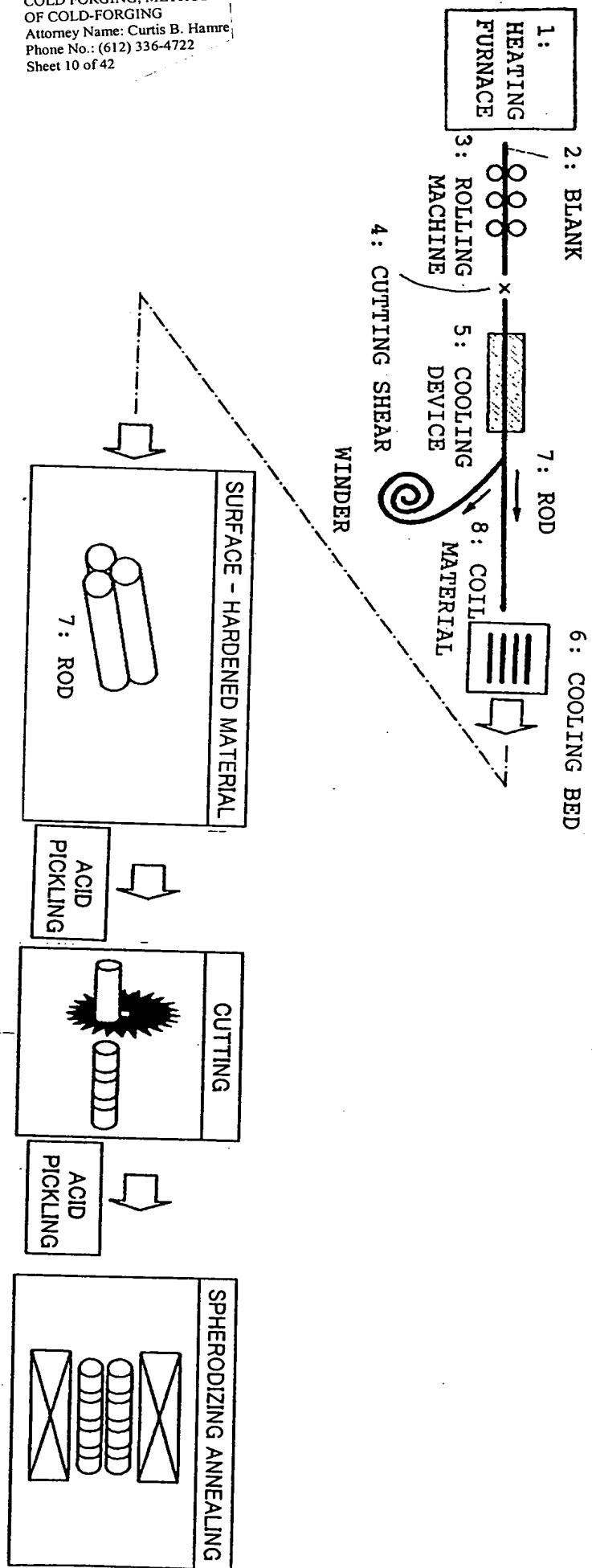
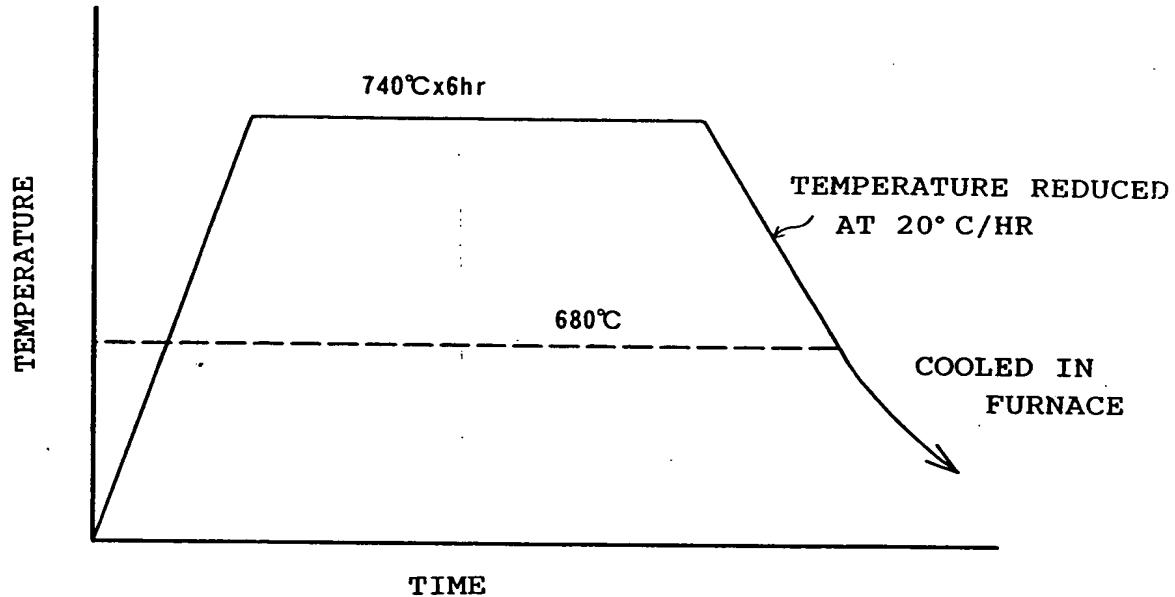
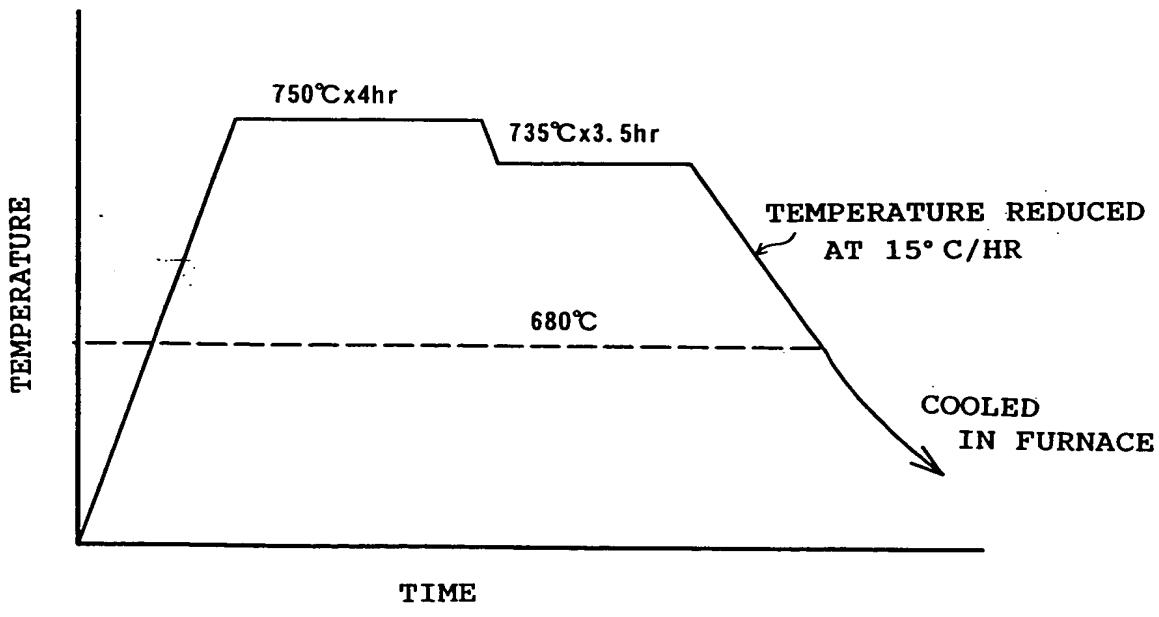


FIG. 11



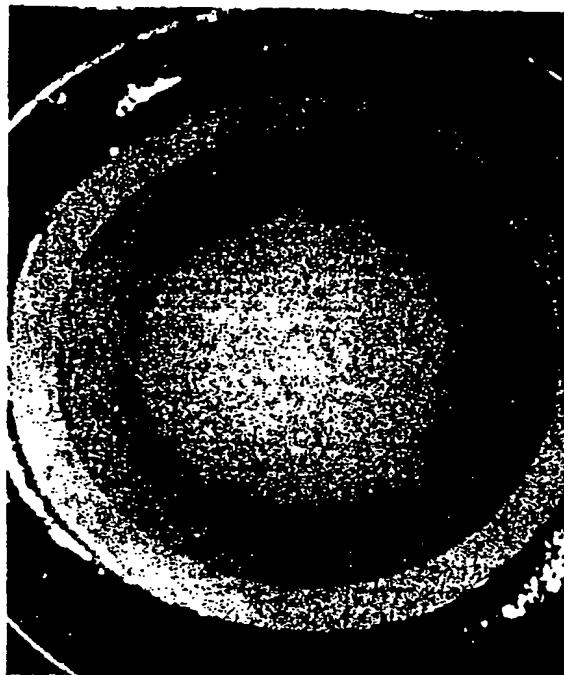
(a)



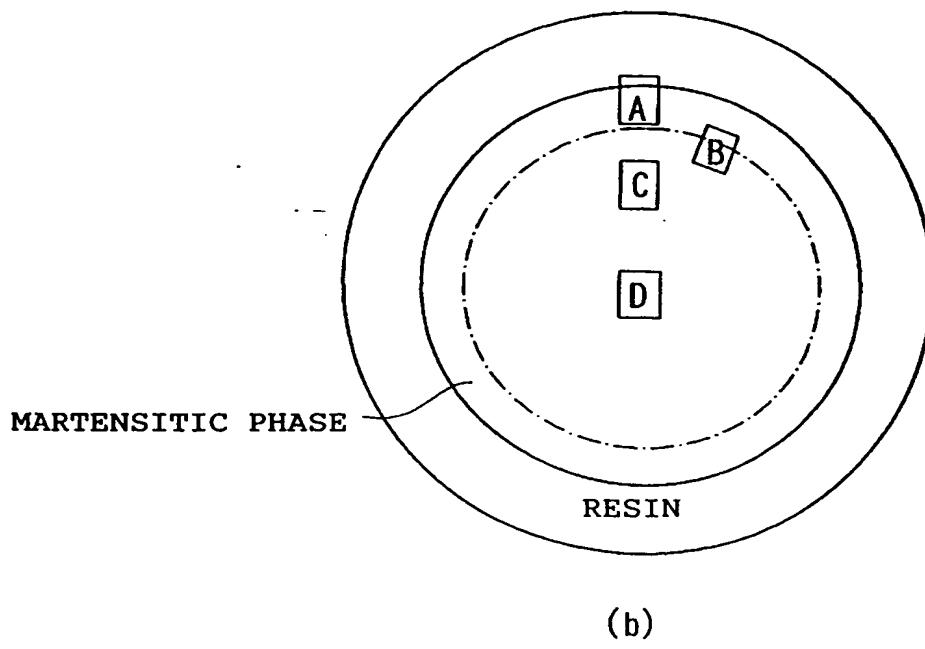
(b)

FIG. 12

BEST AVAILABLE COPY



MARTENSITIC MATERIAL
(a) PRIOR TO SPHERODIZING ANNEALING
 $\times 2.1$



(b)

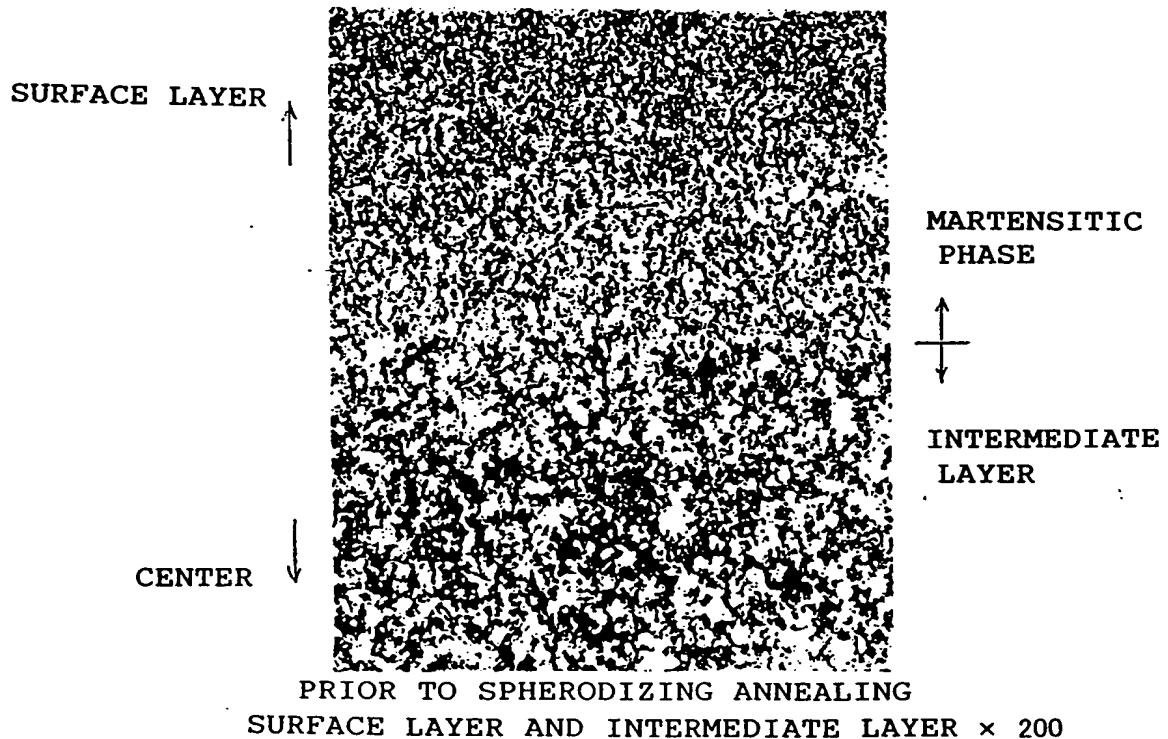
Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
OF COLD-FORGING
Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722
Sheet 13 of 42

FIG. 13



PRIOR TO SPHERODIZING ANNEALING
SURFACE LAYER \times 100

FIG. 14



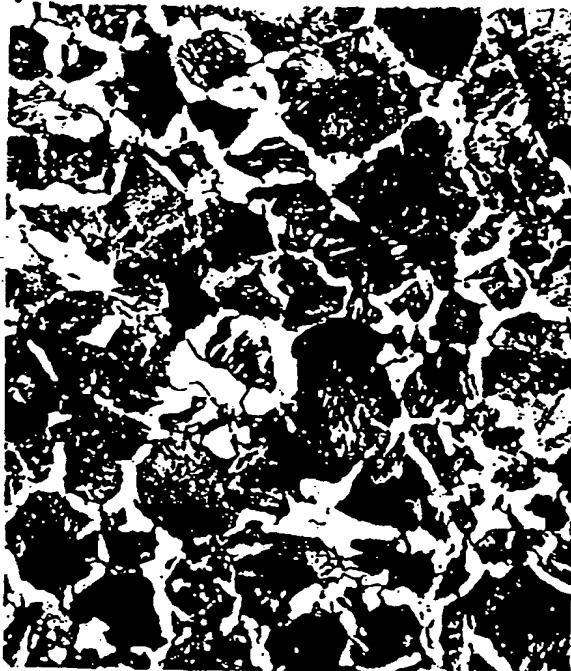
BEST AVAILABLE COPY

FIG. 15



PRIOR TO SPHERODIZING ANNEALING
1/2 R PART \times 400

FIG. 16



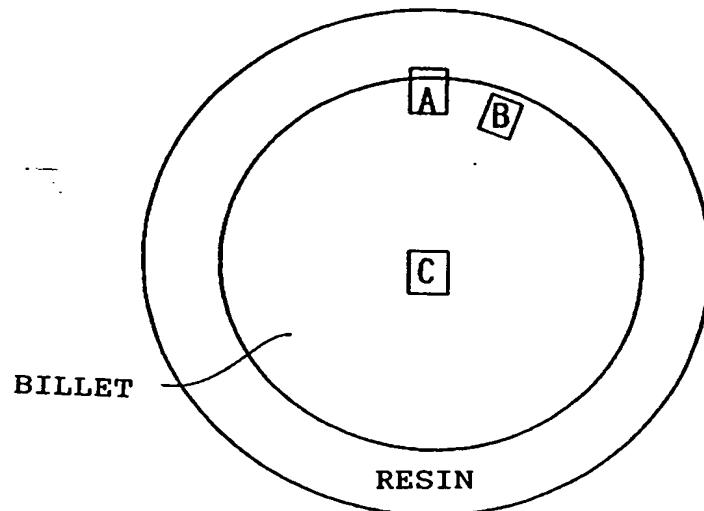
PRIOR TO SPHERODIZING ANNEALING
CENTRAL PART \times 400

FIG. 17



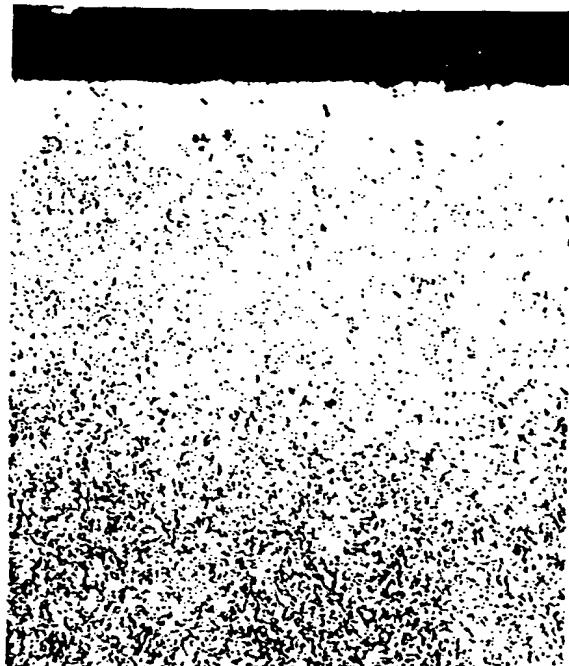
BEST AVAILABLE COPY

(a)



(b)

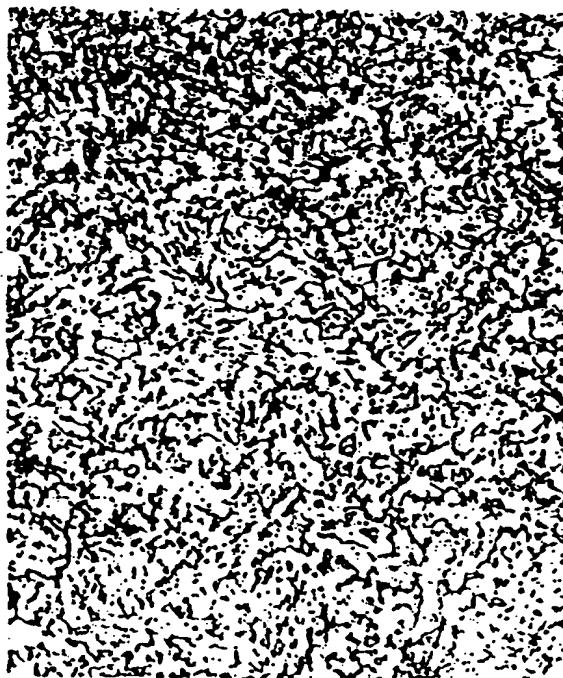
FIG. 18



AFTER SPHERODIZING ANNEALING PATTERN 1
SURFACE LAYER \times 100

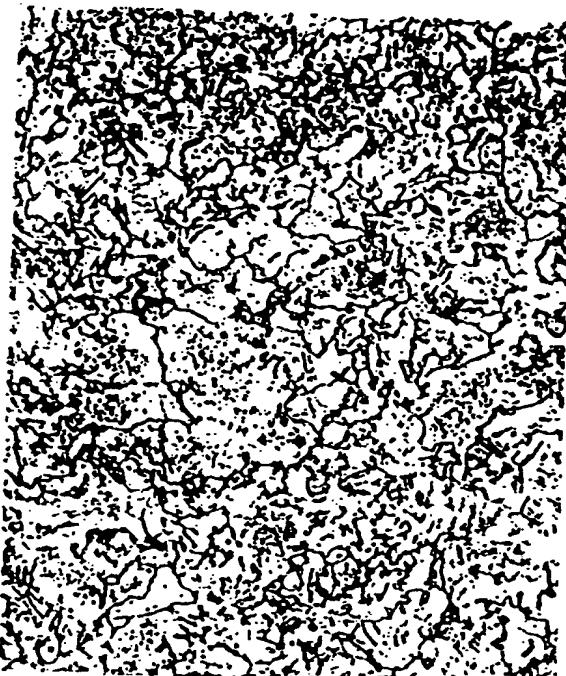
BEST AVAILABLE COPY

FIG. 19



AFTER SPHERODIZING ANNEALING PATTERN 1
SURFACE LAYER \times 400

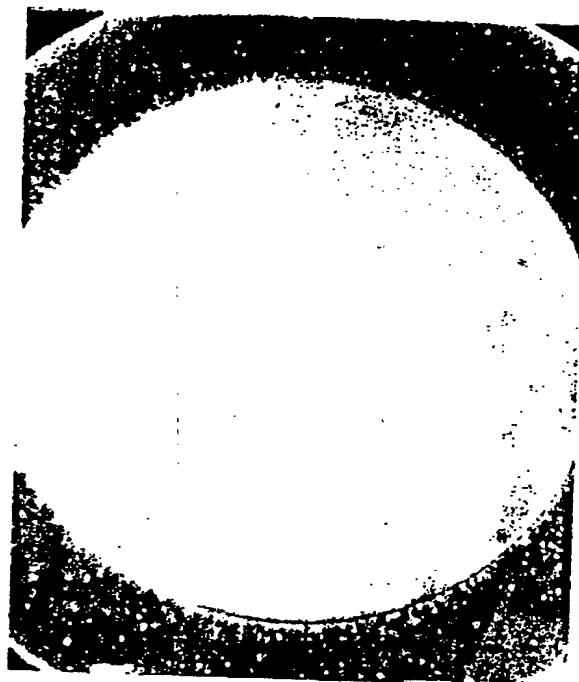
FIG. 20



AFTER SPHERODIZING ANNEALING PATTERN 1
1/2 R PART \times 400

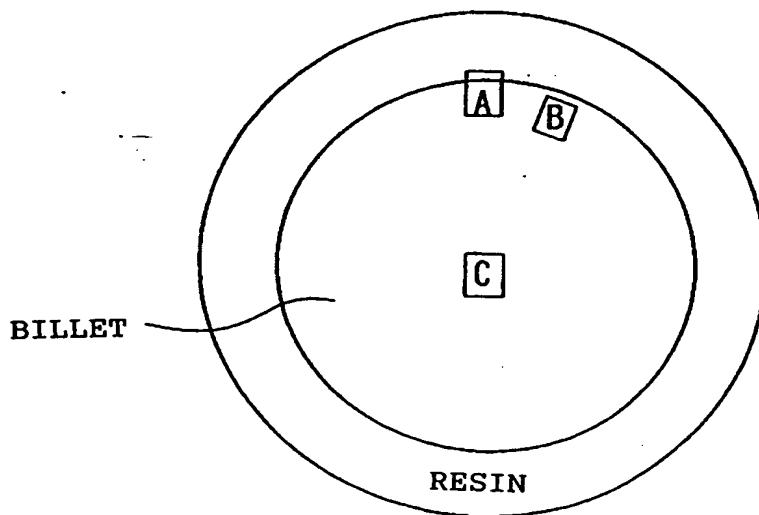
BEST AVAILABLE COPY

FIG. 21



MARTENSITIC MATERIAL
AFTER SPHERODIZING ANNEALING PATTERN 2
x 2. 1

(a)



(b)

BEST AVAILABLE COPY

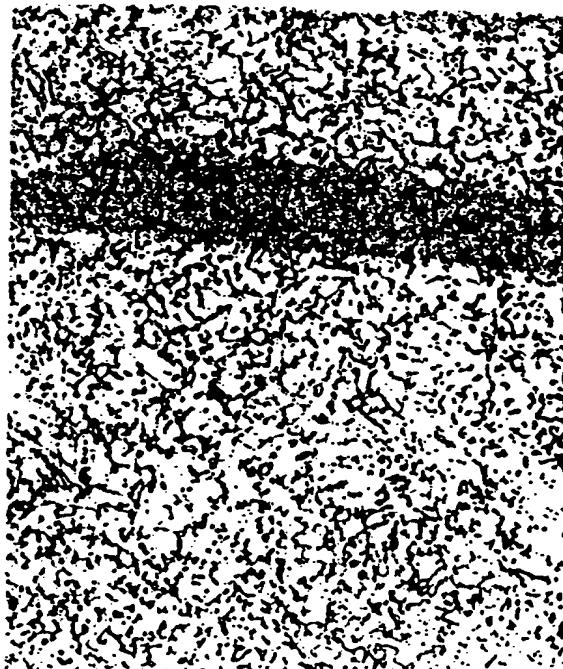
FIG. 22



AFTER SPHERODIZING ANNEALING PATTERN 2
SURFACE LAYER \times 100

BEST AVAILABLE COPY

FIG. 23



AFTER SPHERODIZING ANNEALING PATTERN 2
SURFACE LAYER \times 400

Inventor: Ando, et al
Docket No.: 12052.33USDI
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
OF COLD-FORGING
Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722
Sheet 20 of 42

FIG. 24



AFTER SPHERODIZING ANNEALING PATTERN 2
1/2 R PART \times 400

BEST AVAILABLE COPY

FIG. 25

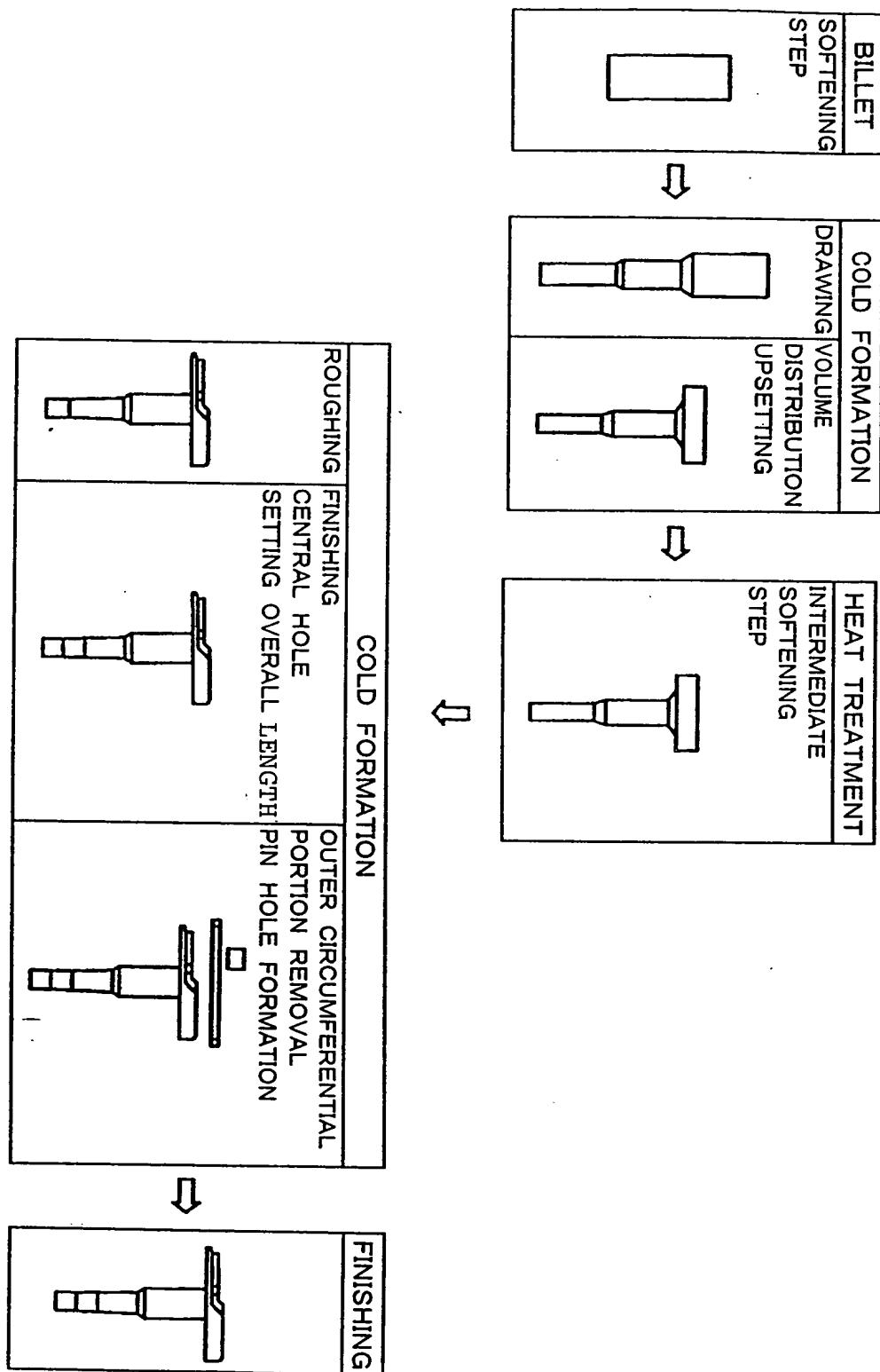


FIG. 26

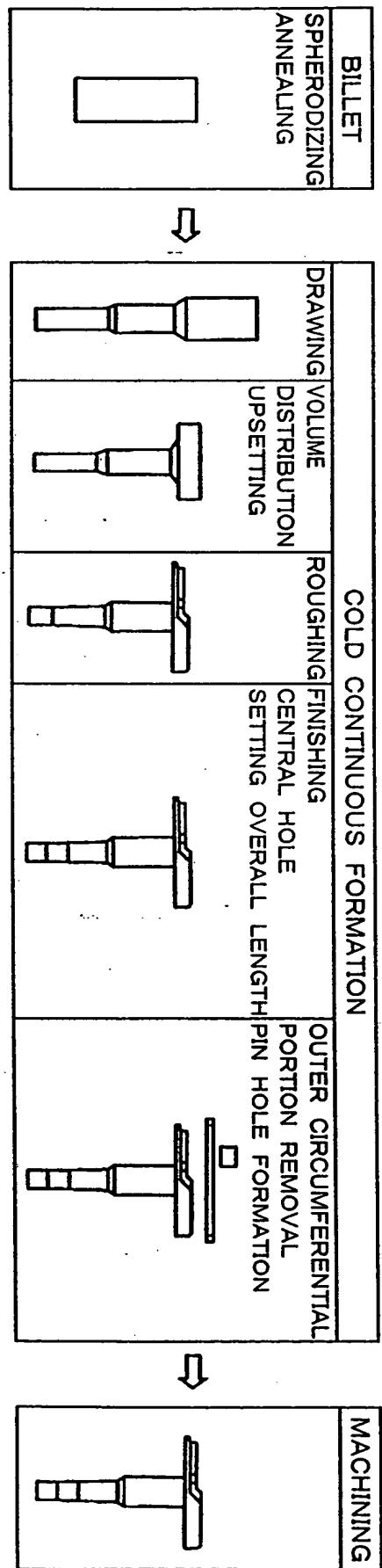


FIG. 27

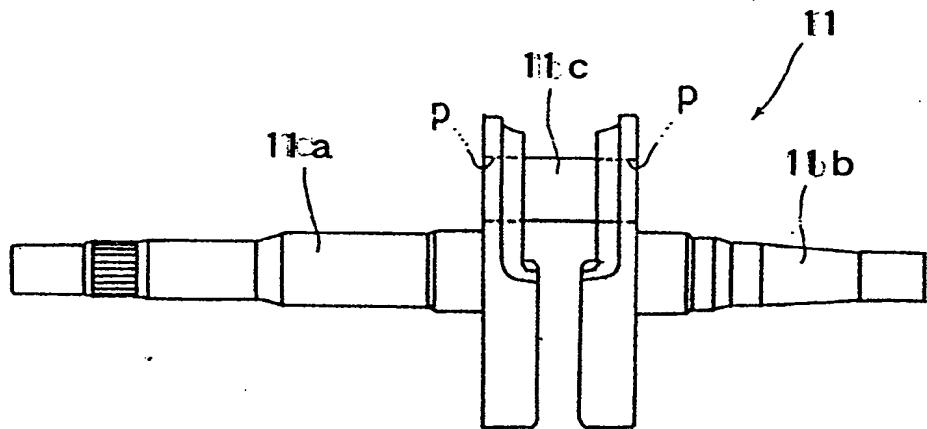


FIG. 28

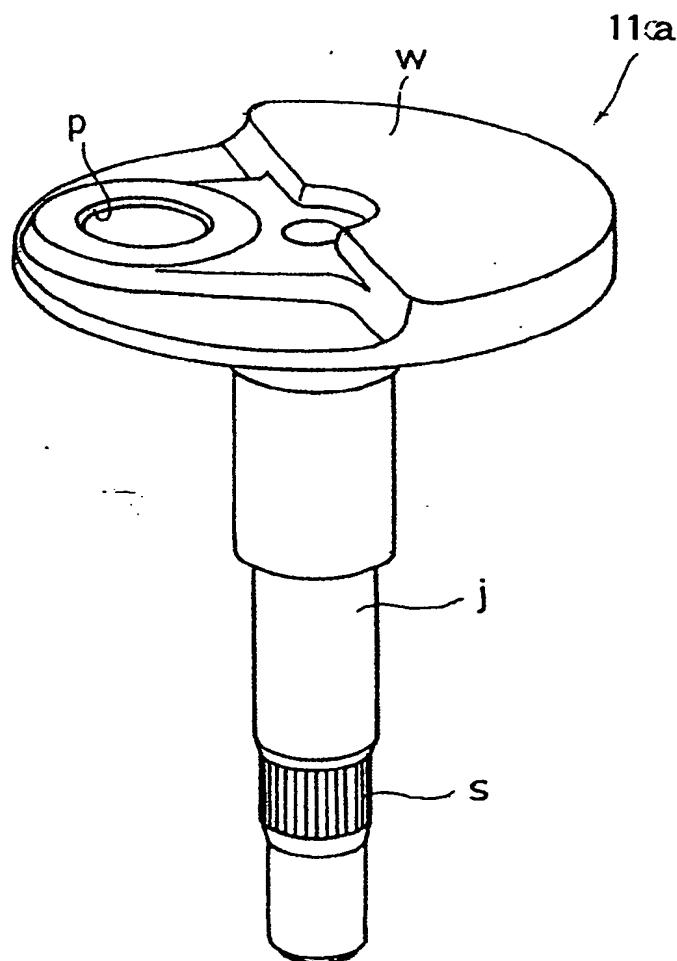


FIG. 29

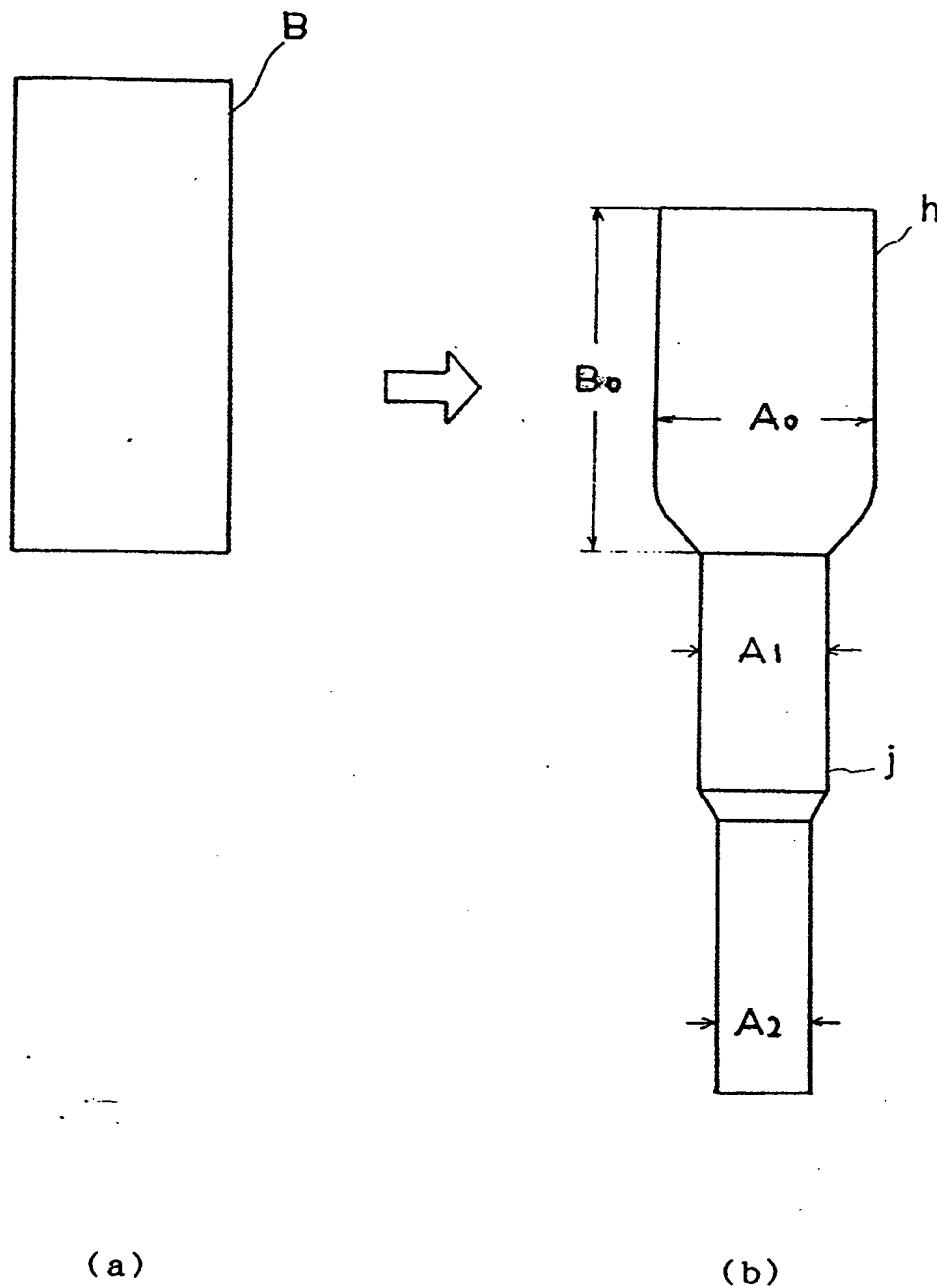
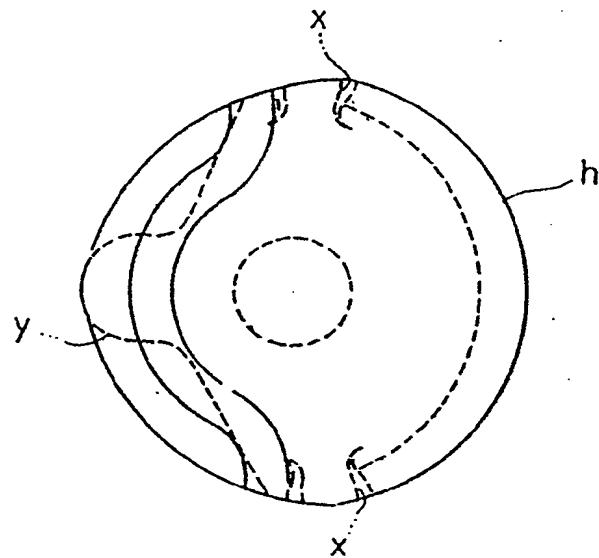
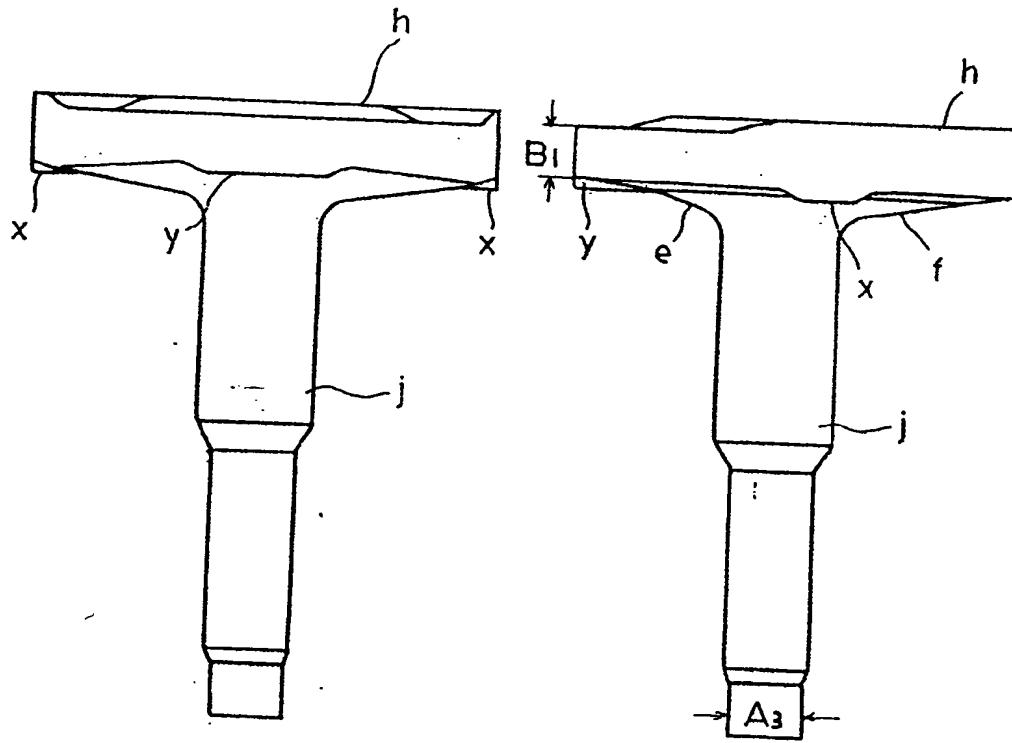


FIG. 30



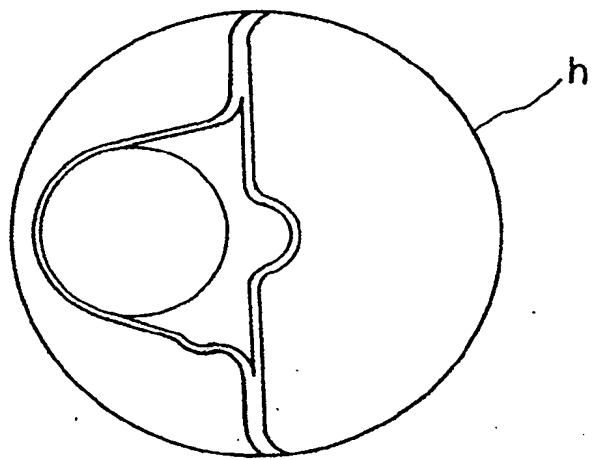
(a)



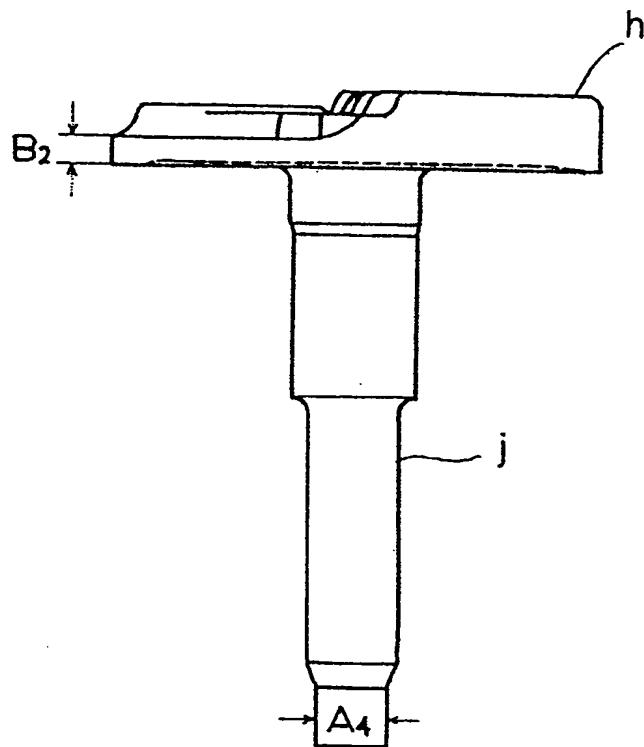
(b)

(c)

FIG. 31

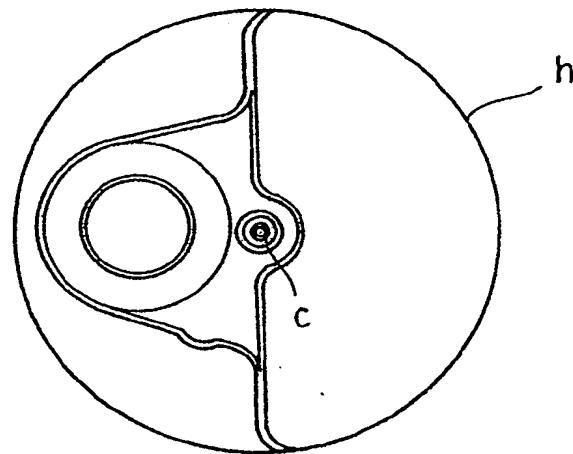


(a)

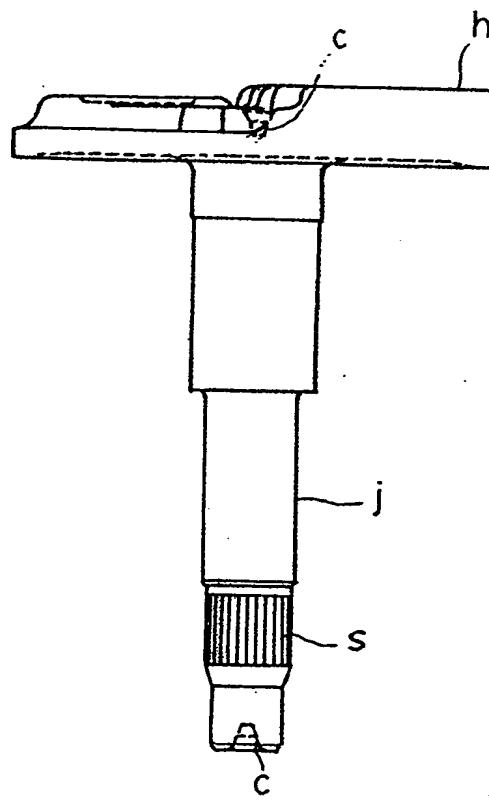


(b)

FIG. 32

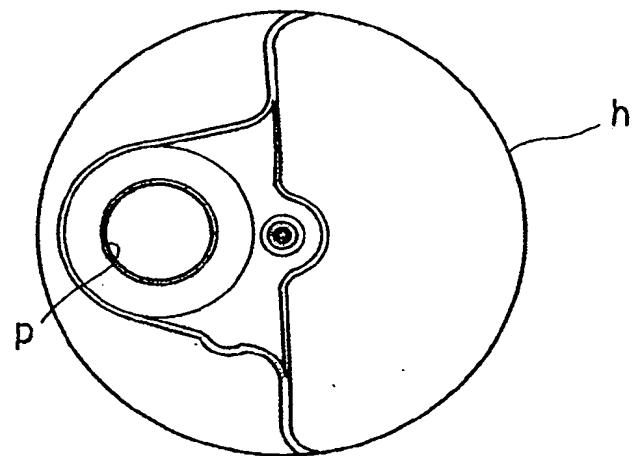


(a)

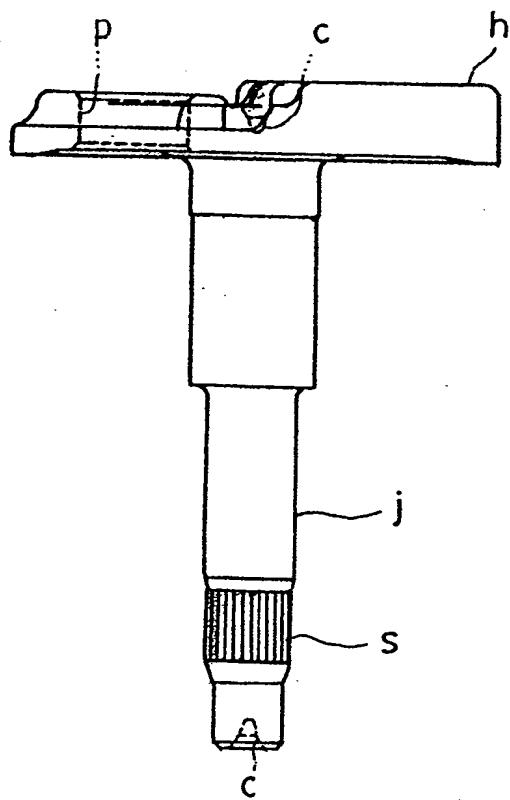


(b)

FIG. 33



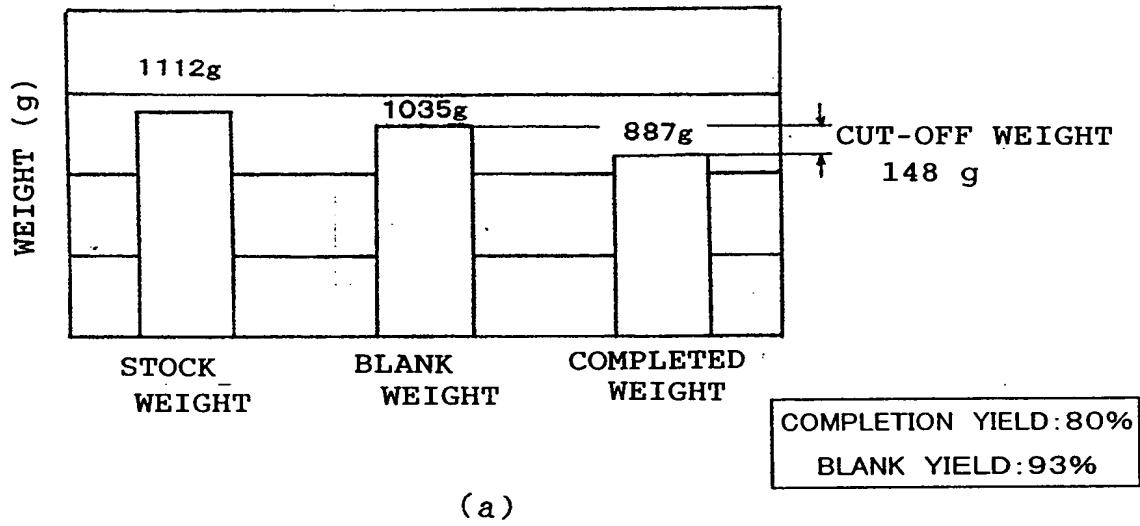
(a)



(b)

FIG. 34

(INVENTIVE COLD-FORGING METHOD)



(CONVENTIONAL COLD-FORGING METHOD)

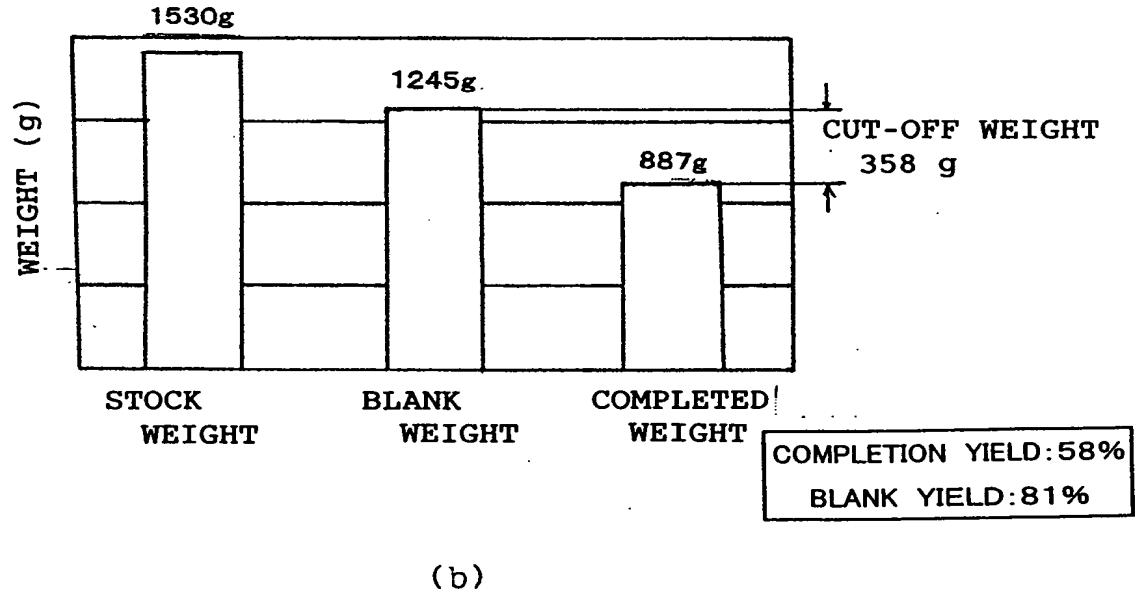


FIG. 35

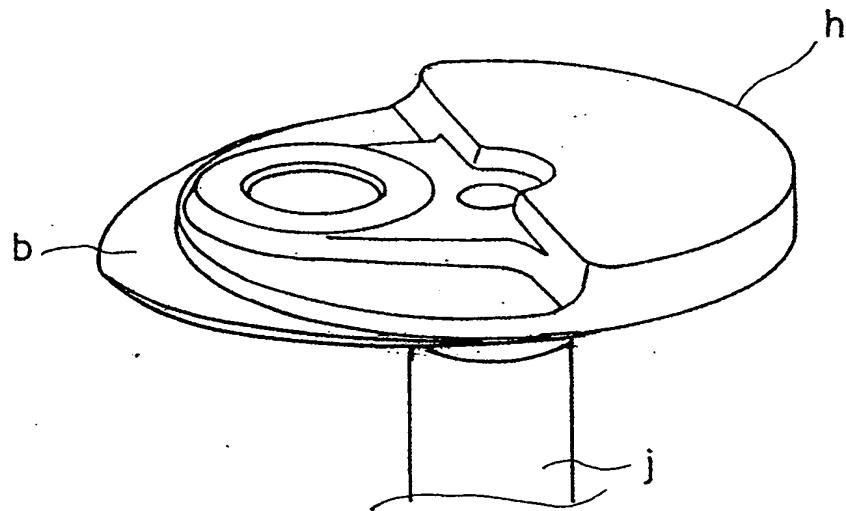
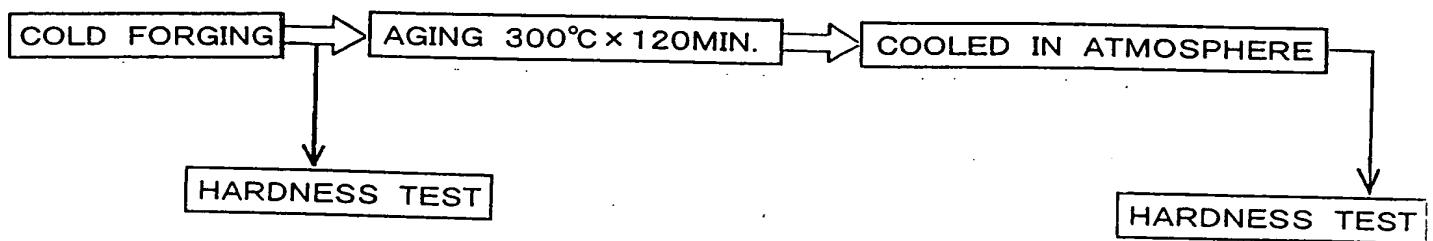
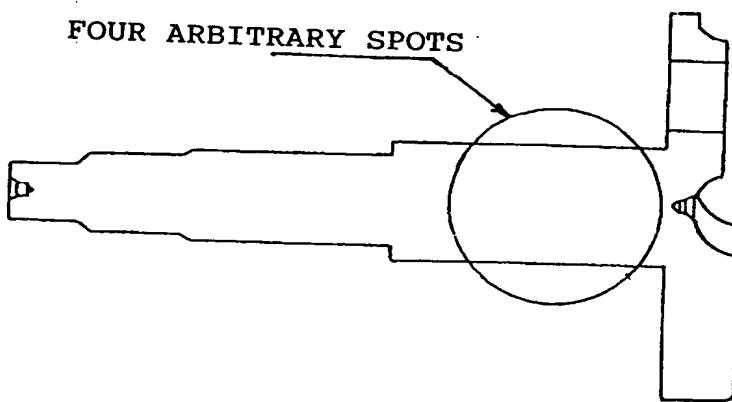


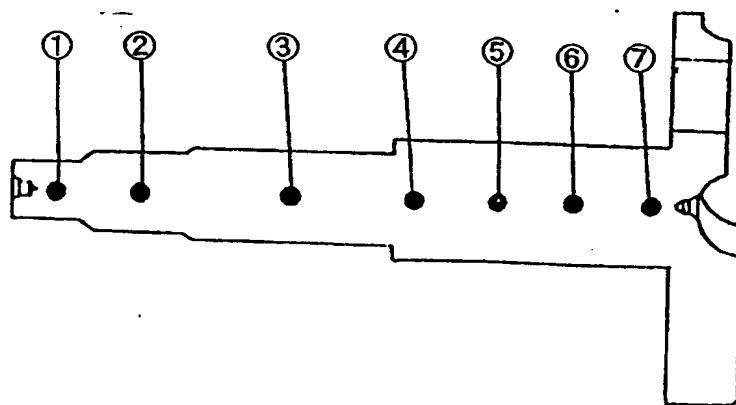
FIG. 36



(a)



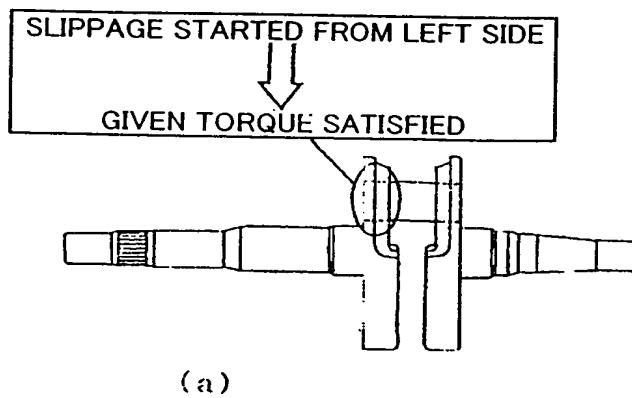
(b)



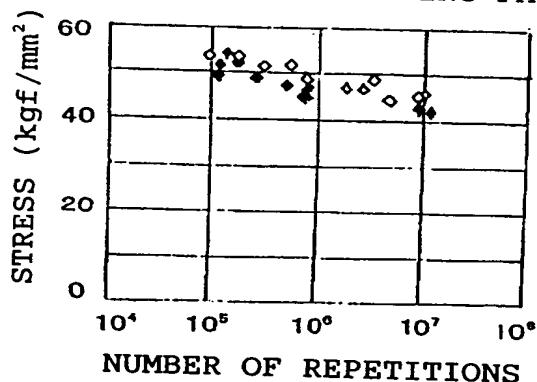
(c)

FIG. 37

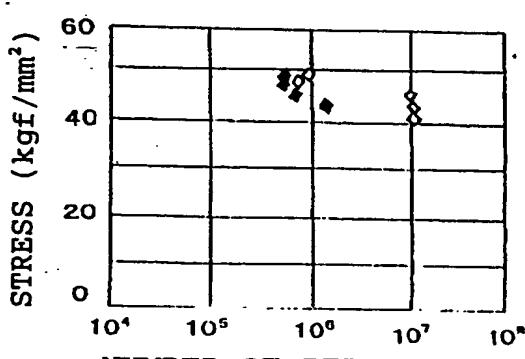
SLIP TORQUE



S - N CURVE (ROTATIONAL BENDING FATIGUE TEST)

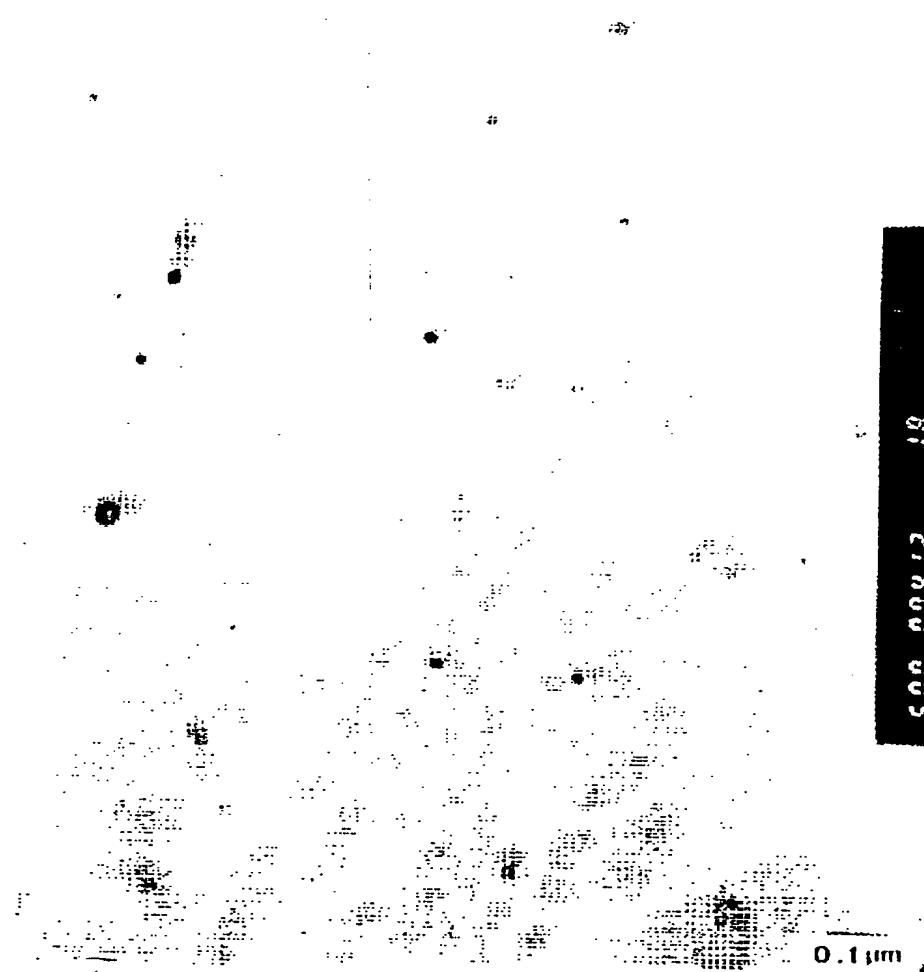


S - N CURVE (SOLID BENDING FATIGUE TEST)



Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
OF COLD-FORGING
Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722
Sheet 33 of 42

FIG. 38



BEST AVAILABLE COPY

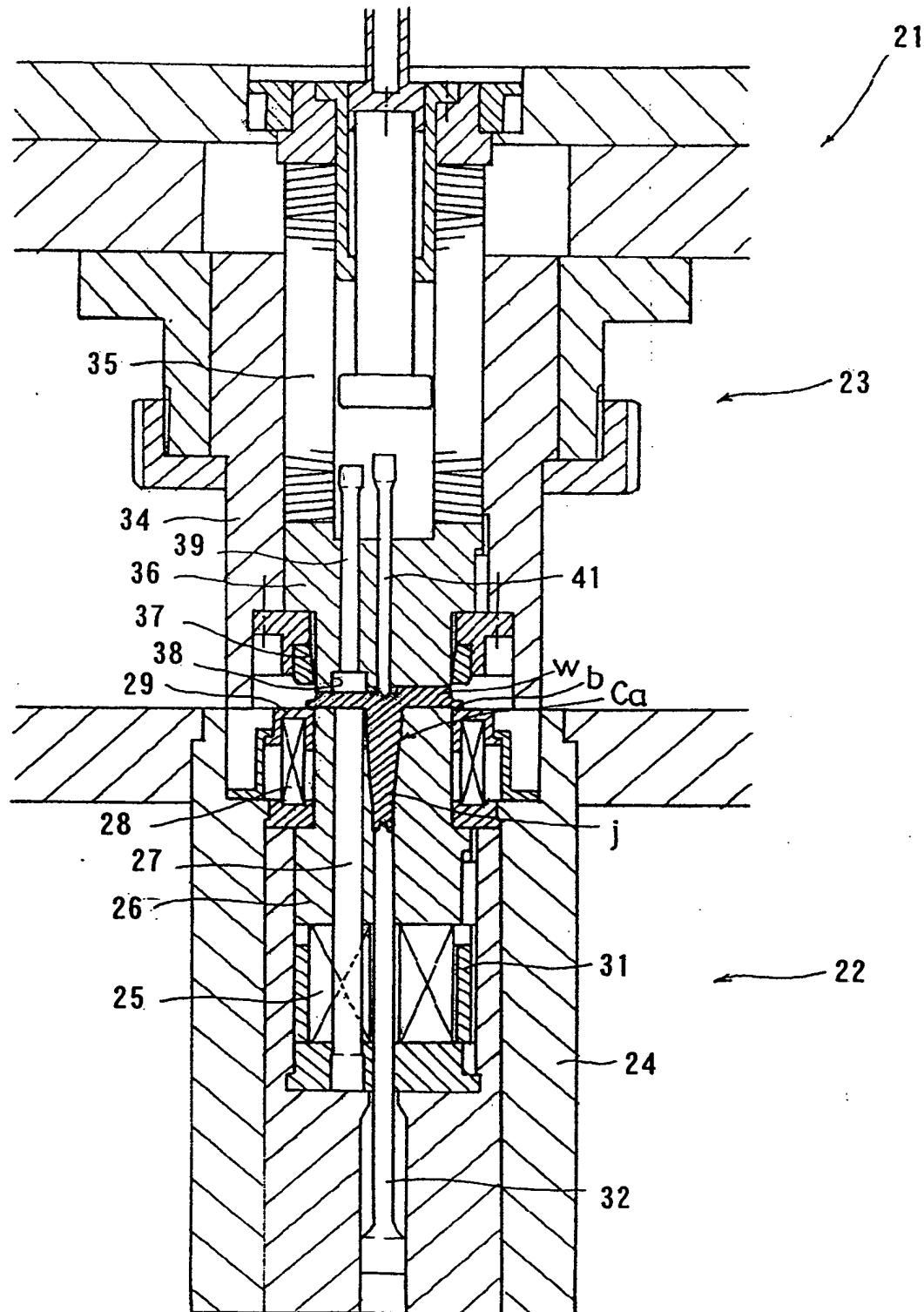
Inventor: Ando, et al
Docket No.: 12052.33USD1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
OF COLD-FORGING
Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722
Sheet 34 of 42

FIG. 39



BEST AVAILABLE COPY

FIG. 40



BEST AVAILABLE COPY

FIG. 41

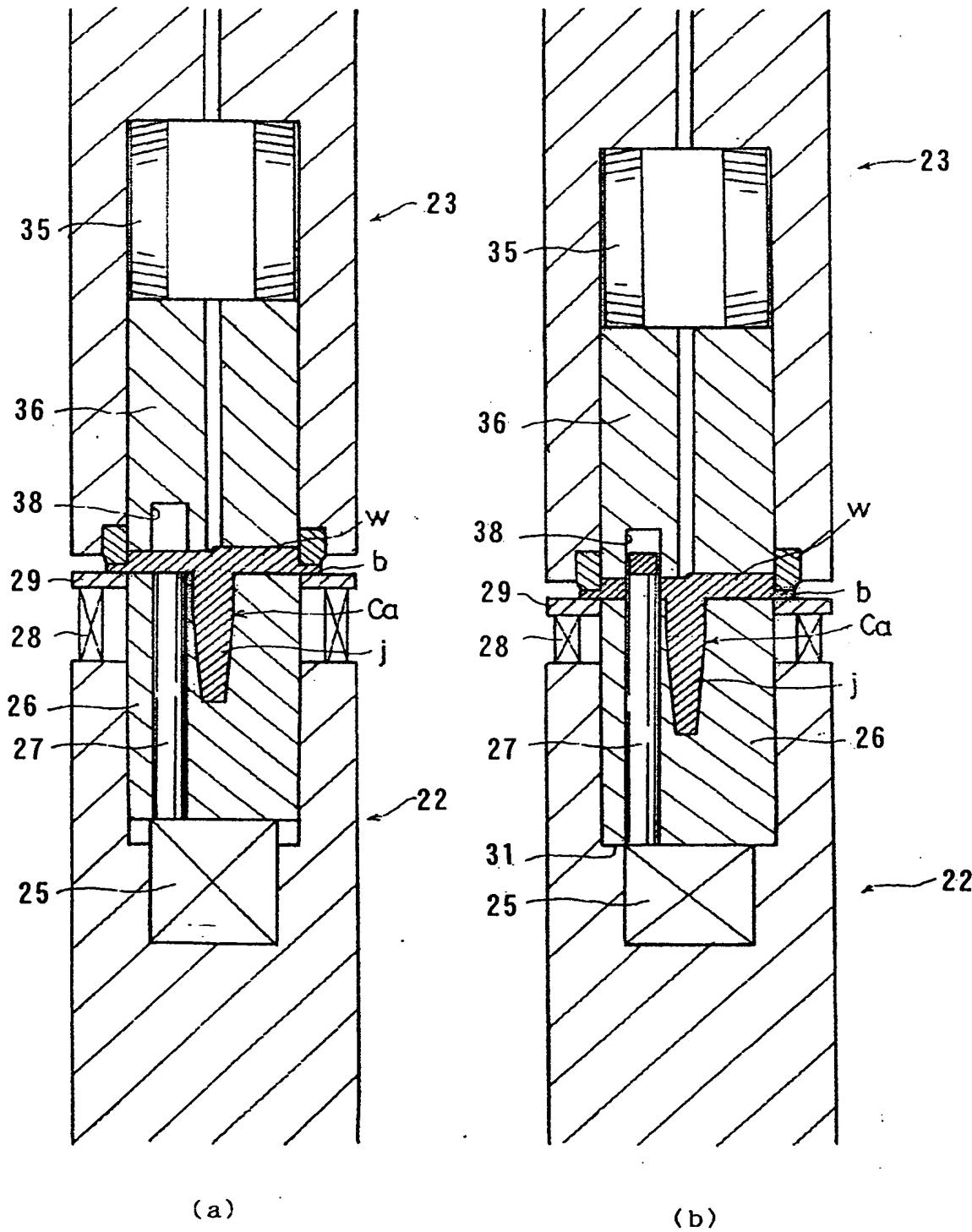


FIG. 42

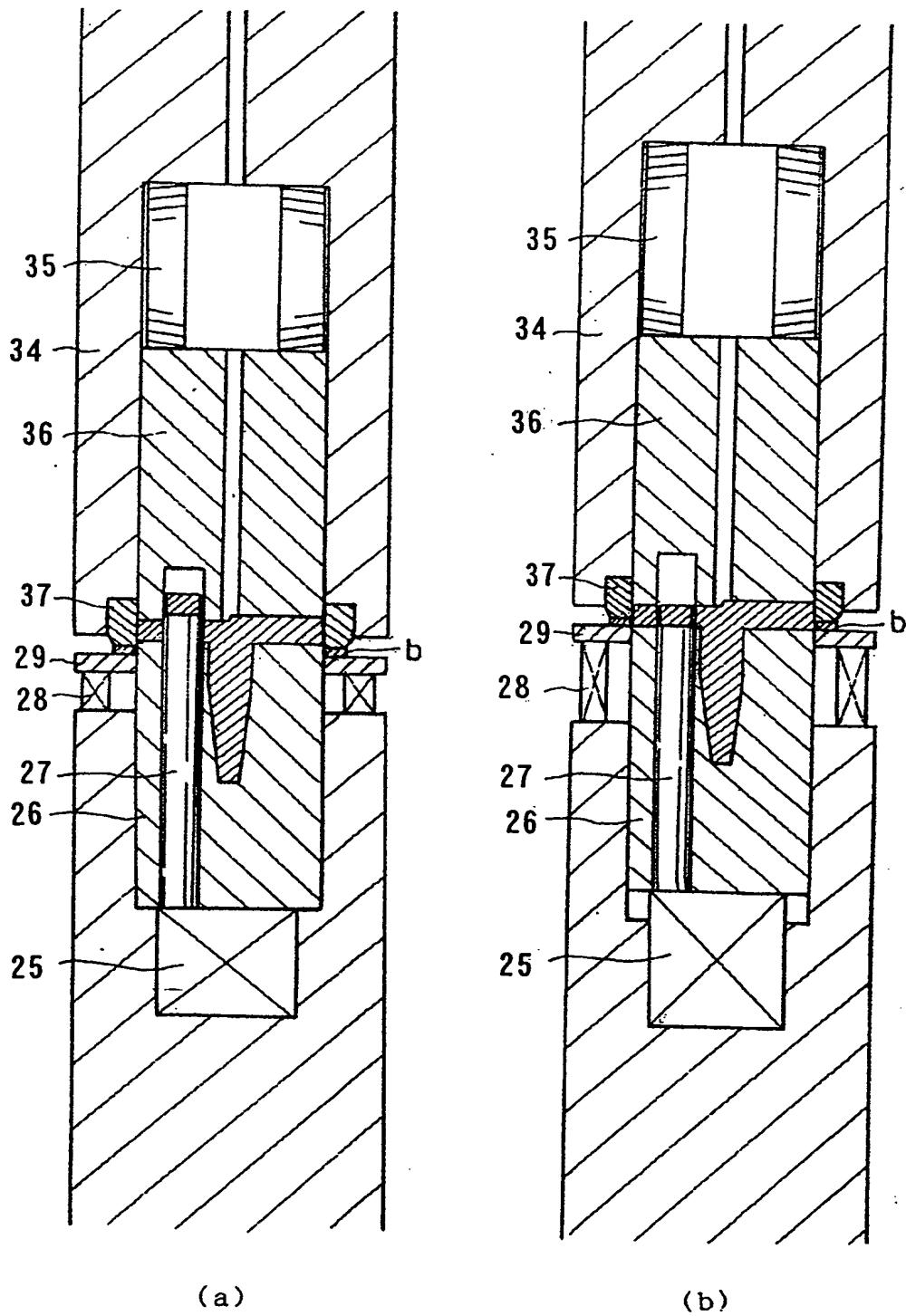
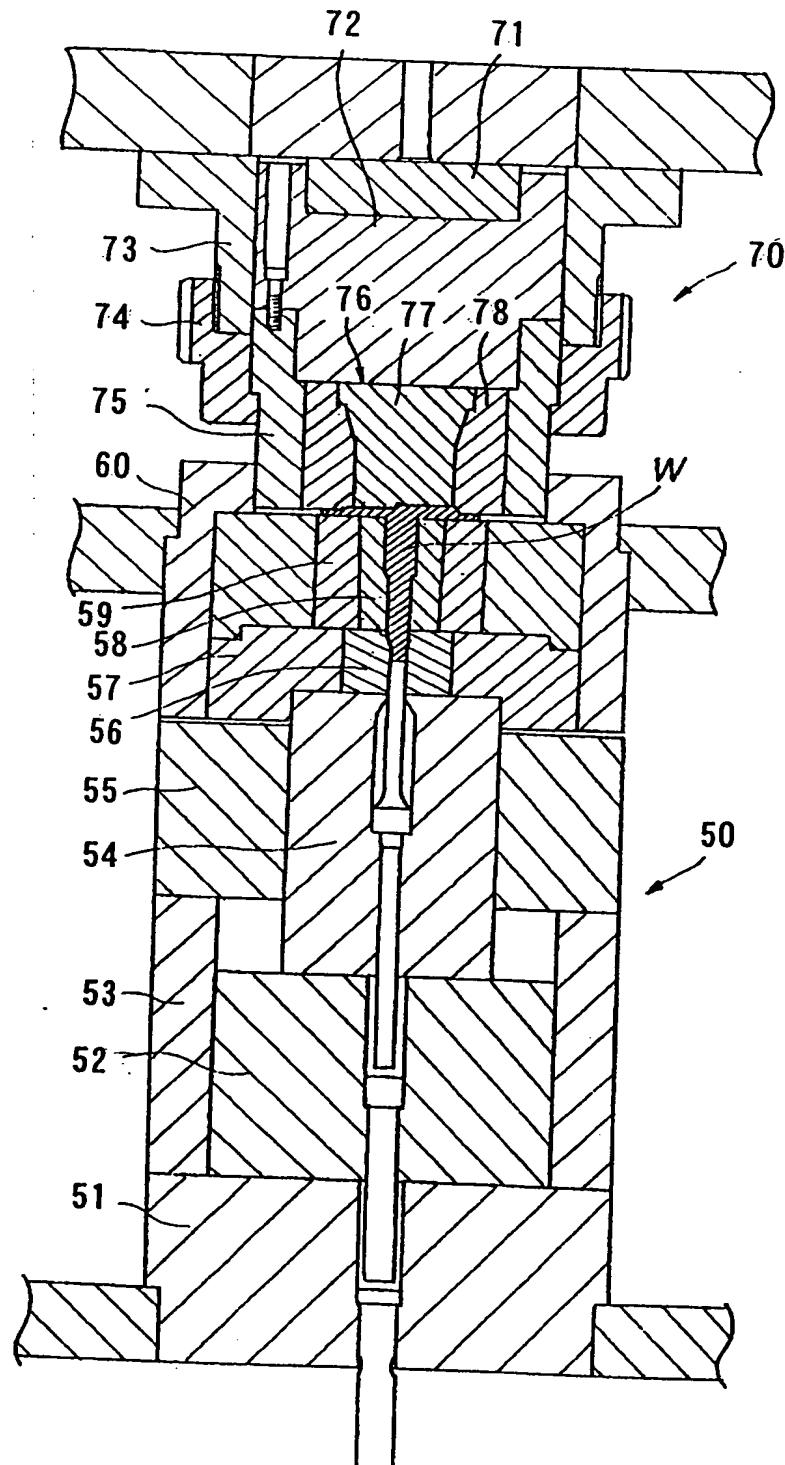


FIG. 43



Inventor: Ando, et al
Docket No.: 12052.33US1
Title: BILLET FOR COLD FORGING, METHOD OF MANUFACTURING BILLET FOR
COLD FORGING, METHOD OF CONTINUOUSLY COLD-FORGING BILLET, METHOD
Attorney Name: Curtis B. Hamre
Phone No.: (612) 336-4722
Sheet 39 of 42

FIG. 44

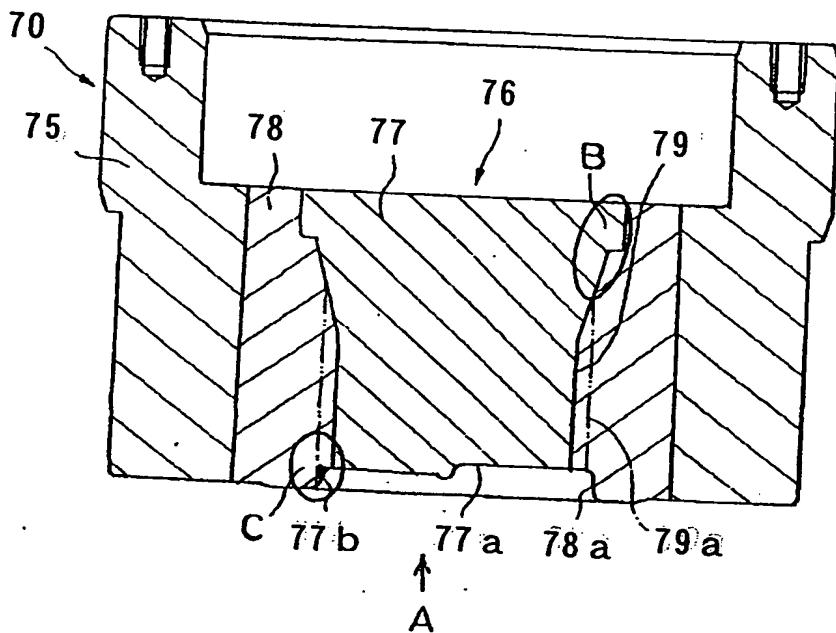


FIG. 45

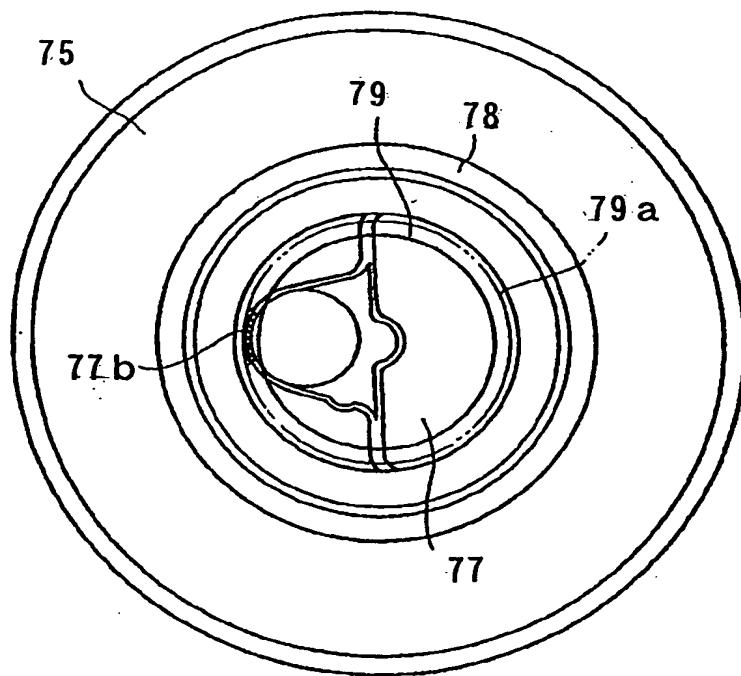


FIG. 46

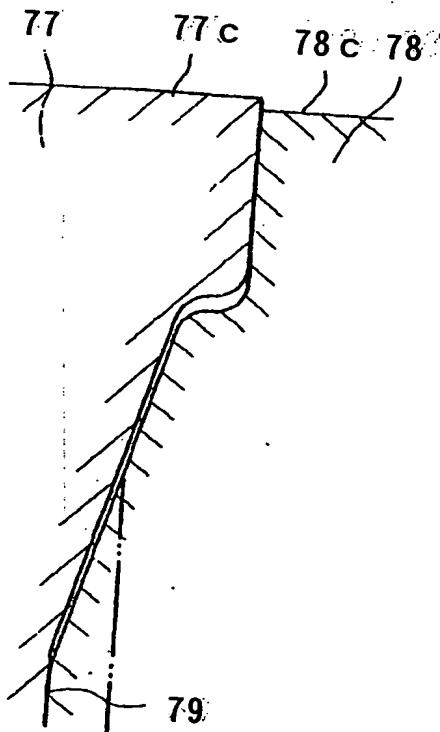


FIG. 47

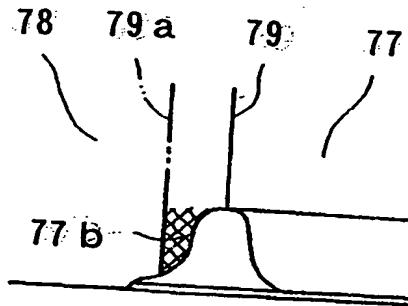


FIG. 48

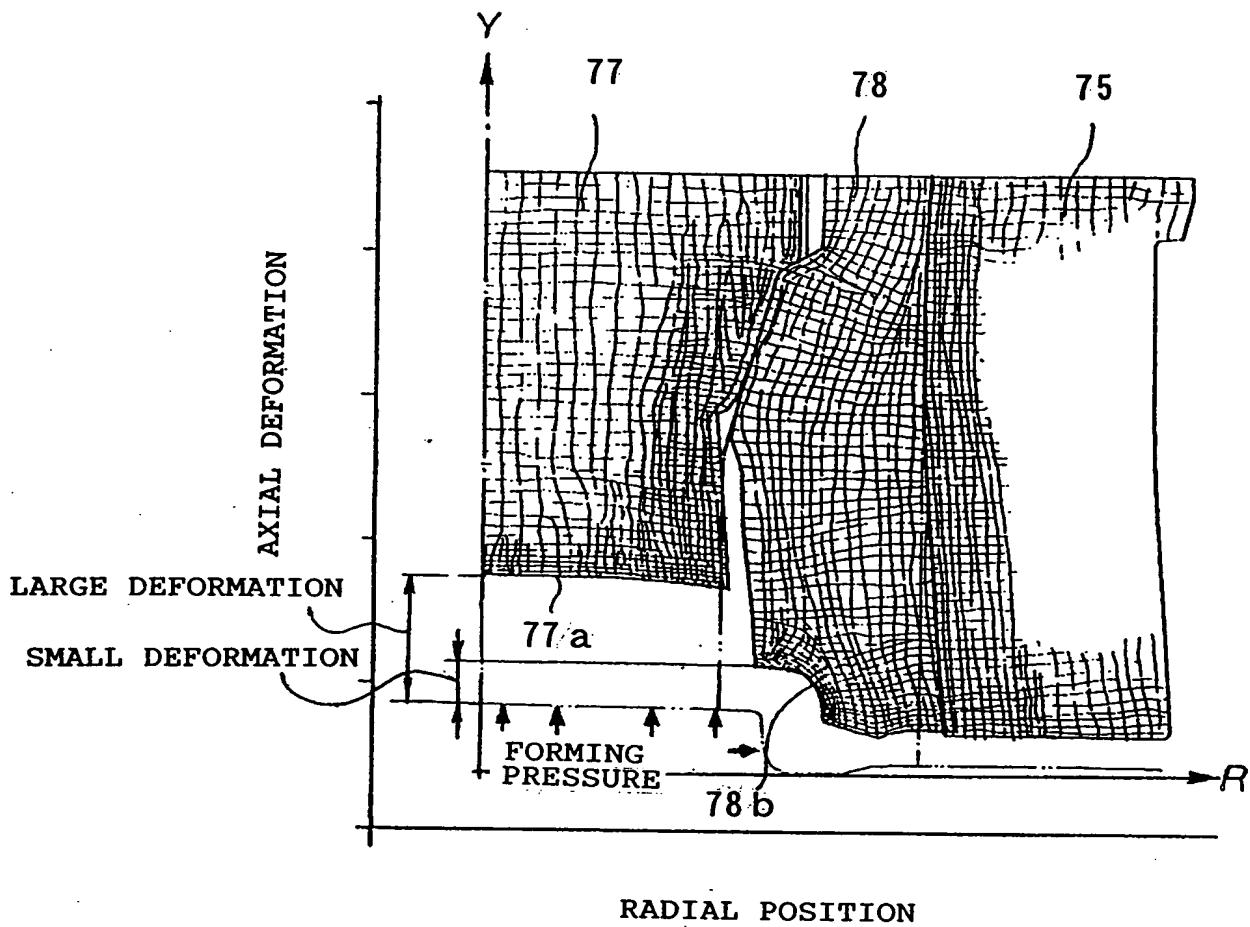


FIG. 49

	Billet manufacturing process					Aspect ratio of carbide (%)	Crack percentage % N=100
	Spherodizing annealing prior to drawing	Drawing	Cutting	Spherodizing annealing subsequent to drawing	Shot bonderizing		
Material 1	None	None	○	○	○	506	35%
Material 2	None	(20%) ○	○	○	○	347	5%
Material 3	○	(20%) ○	○	○	○	300	0%

$$\text{Aspect ratio (\%)} = b/a \times 100$$

